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Publication number: **0 505 251 A2**

**EUROPEAN PATENT APPLICATION**

(21) Application number: 92400684.4

(51) Int. Cl.<sup>5</sup>: C30B 25/08, H01L 21/365,  
H01L 21/00

(22) Date of filing: 16.03.92

(30) Priority: 19.03.91 JP 54974/91  
28.06.91 JP 158241/91

(43) Date of publication of application:  
23.09.92 Bulletin 92/39

(84) Designated Contracting States:  
FR GB

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(54) A method of growing group II-VI mixed compound semiconductor and an apparatus used therefor.

(57) The method comprises the following steps of: providing a reaction chamber (1) comprising a rotatable substrate stage (2), a plurality of nozzles (4-1, 4-2, ..., 4-6) aligned in a line, the nozzle being arranged vertical to a substrate surface, and a mechanism (14, 15) for moving the substrate stage at least in the nozzle alignment direction (Y) and parallel to the substrate surface; disposing the substrate on the substrate stage which is rotated around its axis; flowing a mixed source gas into the reaction chamber through the nozzles, thereby a flow rate of the most reactive gas in the mixed source gas flowing through each nozzle being controlled to increase depending on a distance (D) between the center axis of the substrate rotation and the nozzle; and heating the substrate. An apparatus for applying the above method comprises a particular feature for moving the substrate stage.

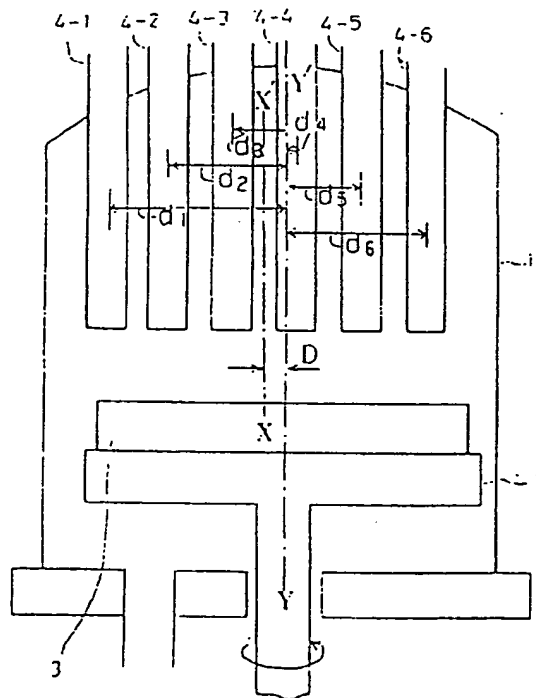


FIG. 5

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## BACKGROUND OF THE INVENTION

1. Field of the Invention

5 This invention relates to a method of growing a mixed compound semiconductor by vapor phase epitaxy and an apparatus used therefor, and more particularly to the method of growing a group II-VI mixed compound semiconductor layer of  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$  and an apparatus used therefor.

The compound semiconductor  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$  has a characteristic of a small energy bandgap and is known as a detector material for infrared rays. The mixing ratio  $x$  included in the above expression  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$  is defined as a ratio of binary compound semiconductor CdTe comprised in ternary compound semiconductor  $\text{HgCdTe}$  and plays an important role to determine the most sensitive wavelength of infrared rays in detection. The present invention relates to the method and apparatus for growing a compound semiconductor layer of  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$  having a uniform  $x$ -value throughout the entire grown crystal layer on a substrate.

15 2. Description of the Related Art

A general concept of growing a mixed compound semiconductor layer of  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$  using an apparatus comprising a reactor chamber of a vertical type is first explained using Figure 1. Figure 1 shows a schematic cross sectional view of the apparatus, wherein a substrate 3 of such as gallium arsenide (GaAs) is disposed on a substrate stage 2 which is rotated around the axis of a center support 10 during the growth. A mixed source gas for growth is supplied into the reactor chamber 1 through a nozzle 4 and the source gas is spouted out vertically onto the substrate 3. In Figure 1, only a single nozzle is illustrated, however, a plurality of nozzle can be substituted therefor. The reactor chamber 1 is arranged on a fixed flange 6 with which an outlet pipe 7 is provided for exhaust. A RF coil 5 is arranged outside the reactor chamber 1 for heating the substrate stage 2 which is made of graphite.

A plurality of gas sources are provided which are shown in Figure 2. A mercury (Hg) bubbler 30 supplies mercury vapor contained in a bubbling hydrogen gas. The mercury bubbler 30 comprises a valve 22, a mass flow controller 23, and a pressure gauge 28. A hydrogen gas is supplied to two mass flow controllers 23 and a partial pressure of mercury contained in the mixed hydrogen source gas is precisely controlled. The similar bubblers 32 and 34 for tellurium and cadmium are respectively also provided, but the details are omitted in Figure 2 for simplicity. A di-isopropyltelluride (abbreviated hereinafter as DIP-Te) bubbler 32 supplies DIP-Te vapor contained in a bubbling hydrogen gas. A dimethylcadmium (abbreviated hereinafter as DM-Cd) bubbler 34 supplies DM-Cd vapor contained in a bubbling hydrogen gas.

During the growth, the above three source gases are mixed and introduced into the reactor chamber 1 through the gas nozzle 4, and the mixed gas is spouted out onto the substrate 3. The rotating substrate stage 2 together with the substrate 3 is heated by the RF coil 5. DIP-Te and DM-Cd source gases are decomposed into element gases, and the decomposed elements and Hg of the Hg source gas react with each other in the reactor chamber 1 forming mixed compound semiconductor  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ , which deposits on the substrate 3 epitaxially on the substrate. The method falls under the category called MOCVD (Metal Organic Chemical Vapor Deposition).

The above method includes the problem that, when source gases are heated in the reaction chamber 1, binary compound semiconductor CdTe is formed much easier than the formation of binary compound semiconductor HgTe. Most of decomposed Cd molecules are consumed on the substrate surface area directly under the nozzle 4, since formation energy of CdTe is smaller than that of HgTe. This results in forming  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$  compound layer which has a higher  $x$ -value on the central portion of the substrate 3 and a lower  $x$ -value on the peripheral substrate area thereof. Therefore, the  $x$ -value of the grown ternary compound semiconductor  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$  is not uniform on the substrate surface.

This is schematically shown in Figure 3. The abscissa shows a position on the substrate 3 which has a diameter  $2r$ , and the ordinate shows an  $x$ -value of the grown compound semiconductor  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$  layer. Figure 3 shows that the grown ternary semiconductor  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$  has a composition such that the  $x$ -value thereof has a peak value at the center of the substrate 3 and gradually decreases toward the periphery thereof.

A plurality of nozzles are used in order to improve a uniformity in  $x$ -values of the grown semiconductor. An exemplary result is shown in Figure 4, in which four nozzles 4-1 to 4-4 are utilized. The result shows a remarkable improvement compared with that shown in Figure 3, however, fluctuation in  $x$ -values is not improved to a satisfactory level.

In order to improve uniformity of the grown semiconductor, the following patent applications have been published. Japanese Unexamined Patent Publication SHO 62-297296 published Dec. 24, 1987 discloses an MOCVD apparatus, wherein a substrate is disposed on a susceptor and rotates around the center axis thereof,

the substrate surface is arranged to be parallel to the gas flow direction, and further the susceptor can move back and forth in the transversal direction to the gas flow. Japanese Unexamined Patent Publication HEI 1-140712 published June 1, 1989 (the same patent was filed to the US PTO and allowed as US Patent No. 4,980,204) discloses a CVD apparatus similar as that described in Figure 4, wherein each gas flow through a plurality of nozzles is individually and precisely controlled. Further, Japanese Unexamined Patent Publication HEI 3-271195 published Dec. 3, 1991 discloses a mechanism for moving a substrate stage in a CVD apparatus, in which a substrate disposed on a substrate stage rotates around the center axis of the substrate and the rotating substrate stage further revolves around the center axis of the CVD apparatus, whereby the substrate stage moves back and forth inwardly and outwardly in the radial direction.

## SUMMARY OF THE INVENTION

It is a general object of the invention to provide a method of growing a mixed compound semiconductor layer on a substrate having an extremely uniform mixing ratio on the substrate surface.

It is another object of the invention to provide an apparatus for applying the above method of growing a mixed compound semiconductor layer.

It is still another object of the invention to provide a method of growing a group II-VI mixed compound semiconductor  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$  layer having almost constant x-values over an entire substrate surface.

It is a further object of the invention to provide an apparatus for applying the above method of growing the mixed compound semiconductor  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$  layer on a substrate.

According to the present invention, these and other objects are achieved by a method of growing a mixed compound semiconductor layer comprising at least three elements utilizing a plurality of source gases, wherein one of source gases is far reactive with another source gas with less amount of applied energy in forming a compound semiconductor, and the method comprises the steps of:

providing a reaction chamber comprising a rotatable substrate stage for disposing a substrate thereon, either a single or a plurality of nozzles aligned in a line, the nozzle being arranged that gas is spouted out vertically onto the substrate surface, and a mechanism for moving the substrate stage at least in the nozzle alignment direction and parallel to the substrate surface; disposing a substrate on the substrate stage which is rotated around its axis; flowing the mixed source gas into the reaction chamber through the nozzle, thereby a flow rate of the most reactive gas in the mixed source gas flowing through the nozzle being controlled to increase depending on a distance between the center axis of the substrate rotation and the nozzle; and heating the substrate.

In order to apply the above method of growing a mixed compound semiconductor, the present invention provides an apparatus which comprises the similar conventional structure of such as a reactor chamber arranged on a fixed flange, a substrate stage and a center support fixed thereto, the center support being rotatable around the center axis thereof, a substrate disposed on the substrate stage, either a single or a plurality of nozzles aligned in a line, the nozzle being arranged that gas is spouted out vertically onto the substrate surface, and a heater for heating the substrate, however, the apparatus of the invention further comprises:

a mechanism for moving the center support of the substrate stage at least in the nozzle alignment direction and parallel to the substrate surface, and a controller for controlling gas flow rate through either the single nozzle or each of the plurality of nozzles depending on a distance between the center axis of the substrate rotation and the nozzle.

Other aspects, objects, and the several advantages of the invention will become apparent to one skilled in the art from the reading of the following disclosure with reference to the drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a schematic cross sectional view of main portion of the prior art apparatus for growing a mixed compound semiconductor layer;

Figure 2 shows a plurality of gas sources, in which mercury (Hg) source gas is formed by flowing hydrogen gas through a bubbler, and other diisopropyltelluride (DIP-Te) and dimethylcadmium (DM-Cd) source gases are shown in a simplified form,

Figure 3 shows schematically the prior art x-value distribution of  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$  layer on a substrate surface using a single nozzle for supplying source gases,

Figure 4 shows schematically the prior art x-value distribution of  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$  layer on a substrate surface using four nozzles for supplying source gases,

Figure 5 shows a schematic cross sectional view of a main portion of an apparatus for applying a first embodied method of the present invention, in which a substrate stage shifts toward the right side by a devi-

ation D.

Figure 6 shows a schematic cross sectional view of a relative disposition of four nozzles and a substrate stage when substrate stage is located at the neutral position in a second embodied method, in which the substrate stage moves toward right and left periodically.

Figure 7 shows a cross sectional view of an apparatus in accordance with the present invention, in which a movable stage together with a center support and a substrate stage moves in the horizontal direction under the control of a controller,

Figure 8 shows a perspective view of another mechanism for moving a center support together with a substrate stage according to the present invention, and

Figure 9 illustrates schematically the movement of the axis of the center support when the mechanism of Figure 8 is used, which shows that the axis of the center support moves substantially linear.

Same or like reference numerals designate same or similar parts throughout the drawings.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A first method of growing a mixed compound semiconductor  $Hg_{1-x}Cd_xTe$  in accordance with the present invention is explained using Figure 5. An apparatus used therein is similar as that shown in Figure 4. The apparatus comprises a reactor chamber 1 of quartz and a substrate stage 2 which is heated by a RF coil (not shown), and a substrate 3 of three inches in diameter is disposed on the substrate stage 2.

The apparatus utilizes six source gas nozzles 4-1, 4-2, to 4-6 aligned in a line, however, as a specific feature of the present invention, the center line of symmetrical nozzle alignment shown by a dot-and-dash line X-X' deviates from a rotation axis (shown by a dot-dash-line Y-Y') of a substrate 3. In the embodiment, each nozzle has an inside diameter of 10 mm and a pitch between two neighboring nozzles is set at 16 mm and a distance between nozzle tip and substrate surface is set at about 25 mm, and further a deviation distance D between lines X-X' and Y-Y' is set at 4 mm. The distance D is about one fourth of the nozzle pitch.

In growing  $Hg_{1-x}Cd_xTe$  compound semiconductor, three source gases of Hg, DIP-TE and DM-Cd, each bubbled by a hydrogen carrier gas, are mixed and supplied to nozzles 4-1 to 4-6. The substrate is heated at a temperature of about 350 °C, and a gas flow rate to each nozzle is controlled at about 1 l/min. In the embodiment, partial pressures of Hg and DIP-Te source gases to six nozzles are equally maintained at  $1.0 \times 10^{-2}$  atm for Hg source gas and  $1.0 \times 10^{-4}$  atm for DIP-Te source gas.

However, as a second specific feature of the invention, partial pressures of DM-Cd source gas to each nozzle are set at different values as shown in Table 1. The above Table 1 shows that partial pressure of DM-Cd varies depending on a distance d (shown  $d_1$  to  $d_6$  in Figure 5) between the center axis of each nozzle and the rotation axis Y-Y'. The larger the distance d is, the higher the partial pressure is.

TABLE 1

Nozzle No.	DM-Cd Partial Pressure in atm
4-1	$20 \times 10^{-5}$
4-2	$15 \times 10^{-5}$
4-3	$5 \times 10^{-5}$
4-4	$1.5 \times 10^{-5}$
4-5	$10 \times 10^{-5}$
4-6	$15 \times 10^{-5}$

In Figure 5, rotation center line Y-Y' deviates to the right side of the line X-X' by distance D, the following inequality relation exists,

$$d_1 > d_6 > d_2 > d_5 > d_3 > d_4. \quad (1)$$

The above fact means that a small area portion on the substrate surface directly under the nozzle 4-1 moves at the fastest speed and that under the nozzle 4-4 moves at the slowest speed. It is found that, in order to grow  $Hg_{1-x}Cd_xTe$  compound semiconductor having a uniform x-value, the partial pressure of the DM-Cd source gas in the mixed source gas should be increased depending on the surface speed of the rotating substrate under the respective nozzle. The result of the above table has proved to produce a very satisfactory uniformity of x-value.

In the prior art method in that the center line X-X' of nozzle alignment is coincident with the rotation axis of the substrate, the above inequality equation (1) is written as follows,

$$d_1(=d_6)>d_2(=d_5)>d_3(=d_4). \quad (2)$$

Therefore the adjustment of DM-Cd gas flow is limited in three step change which is contrary to the six step change of the above embodiment. The increased number of steps which is caused by providing the deviation distance D by the present invention, makes it possible to control the x-value uniformity more precisely such that each nozzle works to supplement the growth on a small area between the two adjacent nozzles after a half rotation of the substrate.

In the first embodiment, the substrate stage 2 rotates around the center axis, however, relative position of the center axis with regard to the nozzle alignment is stationary. In a second embodiment, a rotating stage as a whole moves with respect to the nozzle alignment, which results in a further improvement of the uniformity of x-values of grown  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$  compound semiconductor.

Figure 6 is a schematic cross sectional view of a main arrangement of substrate and nozzles only in the second embodiment for explaining the principle of the invention. In this case, four nozzles 4-1 to 4-4 are utilized, and a substrate stage 2 moves step by step in the transversal direction (horizontal direction in Figure 6) to the gas flow in the following manner. In Figure 6, the substrate stage moves from the original neutral position (herein, this means the center line X-X' of nozzle alignment coincident with the center axis Y-Y' of the substrate stage) toward the right side and returns back to the neutral position moving toward the left side, and next in the similar way, the substrate stage moves from the neutral position toward the left side and returns back again to the neutral position, and these movements constitute one cycle of the growth steps. The mechanism in the apparatus for moving the substrate stage 2 is separately described later.

Each of four nozzles 4-1 to 4-4 has an inside diameter of 10 mm, and an alignment pitch of four nozzles is set to be 20 mm. A substrate 3 is arranged on the substrate stage 2 having a distance of 30 mm apart from the nozzle tips. In the similar way as in the first embodiment, a mixed source gas of Hg, DIP-Te and DM-Cd is supplied to each nozzle, thereby partial pressures of Hg and DIP-Te being kept at constant values of  $1 \times 10^{-3}$  atm and  $1 \times 10^{-4}$  atm respectively for all nozzles irrespective of the substrate stage movement. The substrate 3 is heated at a temperature of about 350 °C.

However, respective DM-Cd partial pressure for each nozzle is precisely controlled at an appropriate value which is determined by a distance between the substrate position directly beneath the respective nozzle tip and the substrate rotation center. Therefore, every time when the substrate moves in the horizontal direction, partial pressure for four nozzles should be changed at the predetermined data, and thus an amount of DM-Cd source gas in the mixed source gas flowing through each nozzle is controlled. The control data are stored in a computer unit attached to the apparatus, which is described later.

The growth method of the second embodiment is explained more definitely following the detailed steps. A first step (hereinafter denoted as Neutral step) begins when the center axis Y-Y' of substrate stage 2 is coincident with the symmetrical center line X-X' of the nozzle alignment. DM-Cd partial pressures for nozzles 4-1, 4-2, 4-3 and 4-4 are controlled at 3.0, 1.0, 1.0 and 3.0 ( $\times 10^{-5}$  atm) respectively, and this condition is maintained for 1 min for the growth. It is assumed that other growth conditions of such as Hg and DIP-Te source gases, substrate temperature, gas flow rate, etc. are maintained constant, therefore they are omitted.

Next as a second step (hereinafter denoted as R-1 step), the substrate stage moves toward the right side by 2 mm, and DM-Cd partial pressures are changed to 3.2, 1.2, 0.8 and 2.8 ( $\times 10^{-5}$  atm) respectively, and this condition is maintained for 1 min for the growth.

Next as a third step (hereinafter denoted as R-2 step), the substrate stage moves further toward the right side by 2 mm (4 mm from the first step), and DM-Cd partial pressures are changed to 3.4, 1.4, 0.6 and 2.6 ( $\times 10^{-5}$  atm) respectively, and this condition is maintained for 1 min for the growth.

Next as a fourth step (hereinafter denoted as R-3 step), the substrate stage moves further toward the right side by 2 mm (6 mm from the first step), and DM-Cd partial pressures are changed to 3.6, 1.6, 0.4 and 2.4 ( $\times 10^{-5}$  atm) respectively, and this condition is maintained for 1 min for the growth.

Next as a fifth step (hereinafter denoted as R-4 step), the substrate stage moves further toward the right side by 2 mm (8 mm from the first step), and DM-Cd partial pressures are changed to 3.8, 1.8, 0.2 and 2.2 ( $\times 10^{-5}$  atm) respectively, and this condition is maintained for 1 min for the growth.

Next as a sixth step (hereinafter denoted as R-5 step), the substrate stage moves further toward the right side by 2 mm (10 mm from the first step), and DM-Cd partial pressures are changed to 4.0, 2.0, 0.2 and 2.2 ( $\times 10^{-5}$  atm) respectively, and this condition is maintained for 1 min for the growth. The above steps are shown in Table 2.

Subsequent growth steps repeat the above steps in the reverse order in the following way,

R-4 => R-3 => R-2 => R-1 => Neutral.

TABLE 2

Step	Distance D	DM-Cd Partial Pres. $\times 10^{-5}$ atm				Time
		4-1	4-2	4-3	4-4	
Neutral	0 mm	3.0	1.0	1.0	3.0	1 min
R-1	2 mm	3.2	1.2	0.8	2.8	1 min
R-2	4 mm	3.4	1.4	0.6	2.6	1 min
R-3	6 mm	3.6	1.6	0.4	2.4	1 min
R-4	8 mm	3.8	1.8	0.2	2.2	1 min
R-5	10 mm	4.0	2.0	0.2	2.2	1 min

TABLE 3

Step	Distance D	DM-Cd Partial Pres. $\times 10^{-5}$ atm				Time
		4-1	4-2	4-3	4-4	
Neutral	-0 mm	3.0	1.0	1.0	3.0	1 min
L-1	-2 mm	2.8	0.8	1.2	3.2	1 min
L-2	-4 mm	2.6	0.6	1.4	3.4	1 min
L-3	-6 mm	2.4	0.4	1.6	3.6	1 min
L-4	-8 mm	2.2	0.2	1.8	3.8	1 min
L-5	-10 mm	2.2	0.2	2.0	4.0	1 min

Thereafter the substrate stage 2 moves toward the left side and returns back to the initial position in the similar way. The growth condition of each step are shown in Table 3, and the growth follows the sequence of L-1, L-2, L-3, L-4, L-5, L-4, L-3, L-2, L-1 and the Neutral, thus completing one cycle of the growth process.

By repeating the above steps of one cycle, the required thickness of  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$  compound semiconductor layer can be obtained.

In the first and second embodiments, a plurality of nozzles are utilized, however, the method of the present invention is not limited to the plural nozzle system. A third embodiment of growth method shows that the method of the present invention can be applied to an apparatus having a single nozzle.

In the third embodiment, a substrate stage 2 moves stepwise to the right side in the way that a distance D between the rotation axis Y-Y' of the substrate stage and the center line X-X' of the single nozzle increases such as 2 mm, 10 mm, 20 mm, 30 mm and 40 mm, thereafter returns back to the initial condition decreasing the distance such as 30 mm, 20 mm, 10 mm and 2 mm. Each step continues for about 1 min. DM-Cd partial pressure in the mixed source gas are controlled to be  $1.0 \times 10^{-5}$ ,  $2.0 \times 10^{-5}$ ,  $4.0 \times 10^{-5}$ ,  $6.0 \times 10^{-5}$  and  $8.0 \times 10^{-5}$  (atm) depending on the distance value of 2 mm, 10 mm, 20 mm, 30 mm and 40 mm respectively. Other conditions are substantially the same as those in the first or second embodiments.

A CVD apparatus for growing a semiconductor layer generally uses a fixed substrate stage in a reaction chamber. The method of growing a mixed compound semiconductor in accordance with the present invention necessitates to use a movable substrate stage in at least one direction. Even in the first embodiment in which the substrate stage is fixed, the substrate stage is arranged have a deviation from the center line of the nozzle alignment. Therefore, it is convenient to use a movable substrate stage in order to adjust the deviation.

Figure 7 shows a cross sectional view of an embodied apparatus for applying the method of the present invention. A substrate 3 is disposed on a substrate stage 2 having a center support 10, which can rotate by a drive mechanism of motor 18 and belt 19. A reactor chamber 1 is provided with, for example, four nozzles 4-1 to 4-4 at the top portion thereof for supplying source gases and arranged on a fixed flange 6, and an outlet pipe 7 for exhaust is provided with the fixed flange 6. Number of nozzles changes depending on a substrate size, reactor chamber size, etc. A movable flange 14 which is connected to the fixed flange 6 by a flexible corrugated tube 11, forms a part of an airtight enclosure and rotatably seals the center support 10 by a magnetic seal 15.

Separately, a movable stage 16 which is movable two-dimensionally in the XY plane, is provided, the XY plane being vertical to the center axis of the reactor chamber, namely, a gas flow direction of the nozzle. The movable stage 16 supports the movable flange 14 and moves it together with center support 10 and substrate

stage 2. The growth method of the present invention needs only one-dimensional movement of the substrate stage, therefore, only a single motor 21 which drives the movable stage 16 in the X-direction, is shown in Figure 7, herein the X-direction being defined for the direction of the nozzle alignment.

Outside the reaction chamber 1 and the other support members previously described, source gas sources for supplying a Hg source gas, DIP-Te source gas and DM-Cd source gas, and a controller 17 are shown, and other system of bubblers and hydrogen carrier gas sources, etc. are omitted for simplicity. Since partial gas pressures of the Hg or DIP-Te source gas supplied to four nozzles 4-1 to 4-4 are equal, only one control valve 22 and one mass flow controller 23 are schematically illustrated, however, with regard to the DM-Cd source gas, gas flow through each of four nozzles should be separately controlled in accordance with the growth method of the present invention. Therefore in Figure 7, control valve 22 and mass flow controller 23 are inserted in each DM-Cd source gas supply line.

Each pair of control valve 22 and mass flow controller 23 are connected to the controller 17 by a control signal line. The motor 21 which moves the movable stage 16 is also connected to the controller 17 by a signal line. The controller comprises an interface unit 24, a data process unit 26, memory unit 25, etc. Necessary data and program for controlling gas flows and movement of the movable stage 16 in accordance with the method of the invention previously described are stored in the memory unit 25.

In applying the first embodiment of the method, six nozzles are provided for the reactor chamber 1, and the motor 21 is controlled at the initial stage of the growth to have the deviation D shown Figure 5, and the substrate stage 2 is fixed at this position in the X-direction and subjected to the rotation control only. Each partial pressure of DM-Cd source gas is controlled in accordance with Table 1.

In applying the second embodiment of the method, the reactor chamber 1 with four nozzle as shown in Figure 7 is utilized. Partial gas pressures of DM-Cd source gas for four nozzles are controlled depending on the movement of the substrate stage 2 as given in Tables 2 and 3.

In applying the third embodiment of the method, the reactor chamber with a single nozzle is enough for the growth. Only DM-Cd partial pressure is controlled depending on the movement of the substrate stage 2 in the X-direction.

The above apparatus of Figure 7 requires the flexible tube 11 and the movable stage 16 which includes a precision mechanism. An easy handling mechanism for moving a center support 10 and a substrate stage 2 is illustrated in Figure 8. A center support 10 integrated with the substrate stage 2 rotates around its center axis in the same way. Two first and second rotatable flanges 14a and 14b are used. The first rotatable flange 14a is inserted concentrically in a fixed flange 6a having a magnetic seal 15a therebetween and, therefore, it can rotate by a motor (not shown) attached thereto. The second rotatable flange 14b is inserted eccentrically into the first rotatable flange 14a having a magnetic seal 15b therebetween. The center support 10 is also inserted eccentrically in the second rotatable flange 14b having a magnetic seal 15c therebetween.

The rotation centers of first and second rotatable flange 14a, 14b and center support 10 are denoted as N, M and O on the XY-plane, and it is assumed that deviation distances of the rotation centers M and O from the rotation centers N and M respectively, namely, distances between N and M, and between M and O have been properly selected. When the first and second rotatable flanges 14a and 14b revolves within the respective specific angle, the axis of the center support 10 (locus of O) moves substantially on a line.

This is schematically illustrated in Figure 9. It is assumed at time  $T_1$ , the center M of second flange 14b is located at  $M_1$  and the center O of center support 10 is located at  $O_1$ . Next at time  $T_2$ , due to the rotation of the first flange 14a,  $M_1$  moves to  $M_2$ , and  $O_1$  moves to  $O_2$ . At time  $T_3$ ,  $M_2$  moves to  $M_3$ , and  $O_2$  moves to  $O_3$ . At time  $T_4$ ,  $M_3$  moves to  $M_4$ , and  $O_3$  moves to  $O_4$ . The loci of  $O_1$ ,  $O_2$ ,  $O_3$  and  $O_4$  are located substantially on a line.

If the deviation distances N-M and M-O, and the back and forth revolving angles of the first and second flanges 14a, 14b are selected at proper values in design computation, substantially linear back and forth movement of the substrate stage 2 in the X-direction can be realized.

The disclosure has been provided with respect to an application for growing the  $Hg_{1-x}Cd_xTe$  compound semiconductor, but it is obvious that the invention may be applied for growing any other compound semiconductor layer involving the similar problem.

## Claims

1. A method of growing a mixed compound semiconductor layer comprising at least three elements utilizing a plurality of source gases, wherein one of source gases is far reactive with another source gas with less amount of applied energy in forming a compound semiconductor (said one source gas is called most reactive source gas), said method comprising the steps of:  
providing a reaction chamber comprising a rotatable substrate stage for disposing a substrate the-



reon, either a single or a plurality of nozzles aligned in a line (x-direction), the nozzle being arranged that gas is spouted out vertically onto the substrate surface, and means for moving the substrate stage at least in the x-direction and parallel to the substrate surface,

disposing a substrate on said substrate stage which is rotated around its axis,

flowing mixed said source gas into the reaction chamber through said nozzle, thereby a flow rate of said most reactive gas in the mixed source gas flowing through said nozzle being controlled to increase depending on a distance between the center axis of the substrate rotation and said nozzle, and heating said substrate.

2. A method of growing a mixed compound semiconductor as recited in claim 1, wherein in case of a plurality of nozzles are used, flow rates of other source gases except said most reactive source gas flowing through the plurality of nozzles are kept substantially constant.
3. A method of growing a mixed compound semiconductor as recited in claim 2, said method further comprising the steps of:
  - moving said substrate stage stepwise in the X-direction, and
  - adjusting said flow rate of the most reactive source gas flowing through each nozzle corresponding to the change of said distance, thereby the flow rate of the other source gases being kept unchanged.
4. A method of growing a mixed compound semiconductor as recited in claim 3, wherein said stepwise movement of the substrate stage comprises periodical movements toward a positive X-direction and a negative X-direction.
5. A method of growing a mixed compound semiconductor as recited in claim 4, wherein the maximum distance of said movement toward positive and negative X-directions is about a half pitch of said nozzle alignment.
6. A method of growing a mixed compound semiconductor as recited in claim 2, wherein the center axis of said substrate stage is located at the fixed point which is apart from the symmetrical center line of the nozzle alignment by a predetermined distance.
7. A method of growing a mixed compound semiconductor as recited in claim 6, wherein said predetermined distance is about one fourth of a pitch of said nozzle alignment.
8. A method of growing a mixed compound semiconductor as recited in claim 1, wherein said mixed compound semiconductor is of a II-VI group ternary compound semiconductor, and said source gases comprise two source gases, each comprising a different element selected among group II elements, and one source gas comprising one element selected among group VI elements.
9. A method for growing a mixed compound semiconductor layer as recited in claim 8, wherein said mixed compound semiconductor is of  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ , and said source gases comprise mercury and dimethylcadmium and diisopropyltelluride respectively, and the dimethylcadmium source gas is said most reactive source gas.
10. An apparatus for growing a mixed compound semiconductor comprising a reactor chamber arranged on a fixed flange, a substrate stage for disposing a substrate and a center support fixed to the substrate stage, the center support being rotatable around the center axis thereof, either a single or 3 plurality of nozzles aligned in a line, the nozzle being arranged that gas is spouted out vertically onto the substrate surface, and means for heating the substrate, said apparatus further comprising:
  - means for moving said center support of the substrate stage at least in said nozzle alignment direction and parallel to the substrate surface, and
  - means for controlling either a gas flow rate through said single nozzle or through each of said plurality of nozzles depending on a distance between the center axis of the substrate rotation and said nozzle.
11. An apparatus for growing a mixed compound semiconductor as recited in claim 10, wherein said means for moving the center support comprises a movable flange and a movable stage mutually fixed with each other, the movable flange being connected to said fixed flange by a flexible tube and provided with means for supporting said center support rotatably and airtightly, said center support penetrating through the flexi-

ble tube and the fixed flange into said reaction chamber, and the movable stage being movable in said direction and parallel to the substrate surface under the control of said controlling means.

- 5 12. An apparatus for growing a mixed compound semiconductor as recited in claim 10, wherein said means for moving the center support comprises a first and second rotatable flange and means for revolving the first and second rotatable flanges back and forth within a respective specified angle, said center support rotatably and airtightly engaged in the second rotatable flange, wherein the first rotatable flange is rotatably and airtightly engaged in said fixed flange, the second rotatable flange is rotatably and airtightly engaged in the first rotatable flange, the rotation center of the second rotatable flange has a first deviation distance from the rotation center of the first rotatable flange, and the center of the center support has a second deviation distance from the rotation center of the second rotatable flange, whereby the center of said center support moves substantially on a line by proper selection of the first and second deviation distances.
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- 55

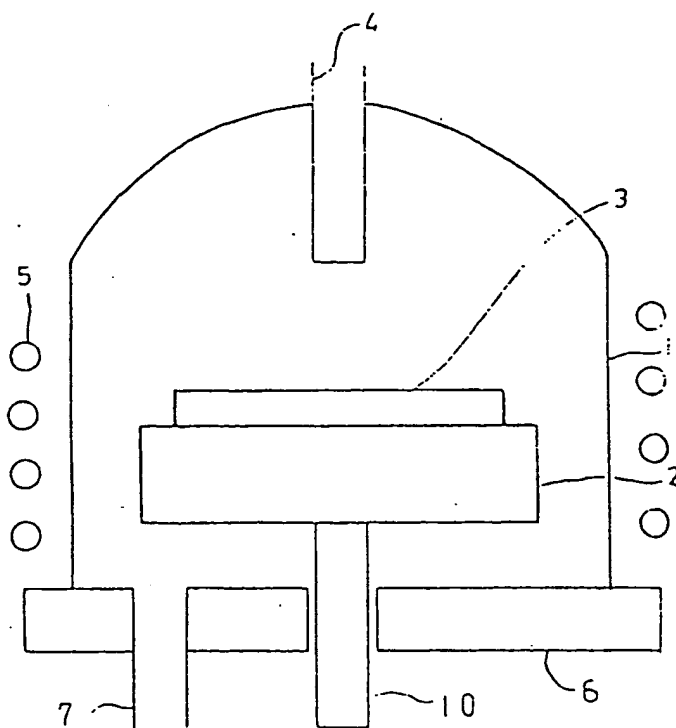


FIG. 1 PRIOR ART

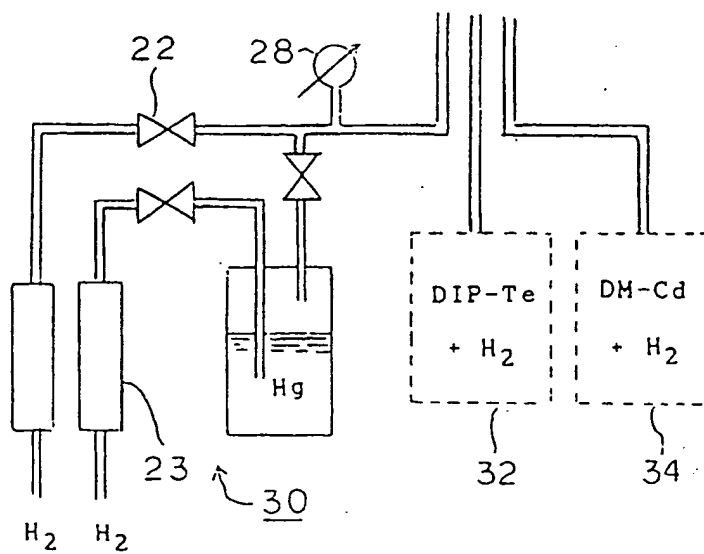


FIG. 2 PRIOR ART

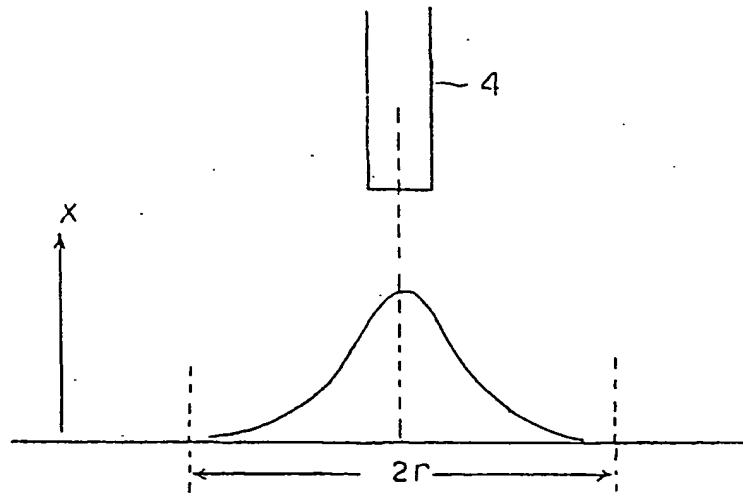


FIG. 3 PRIOR ART

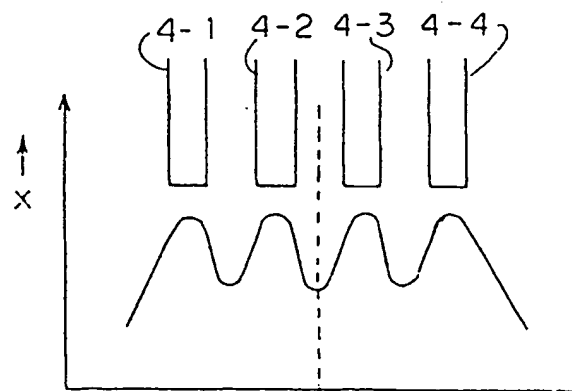


FIG. 4 PRIOR ART

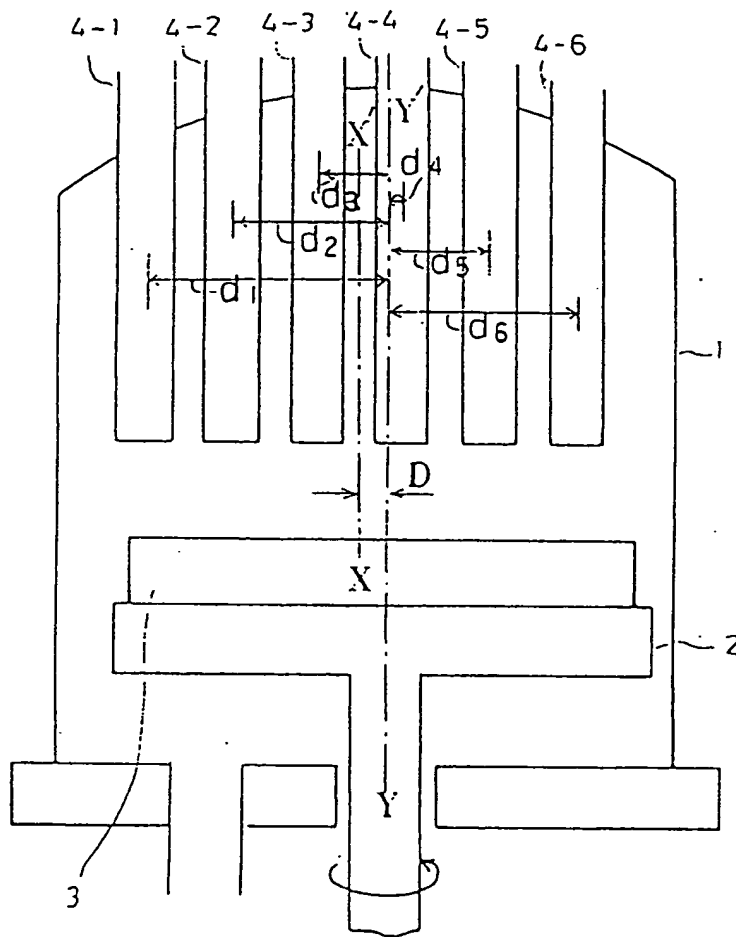


FIG. 5

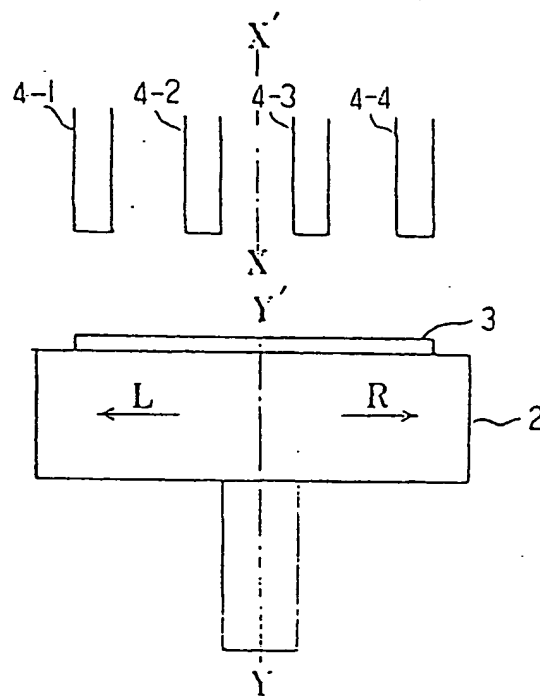


FIG. 6

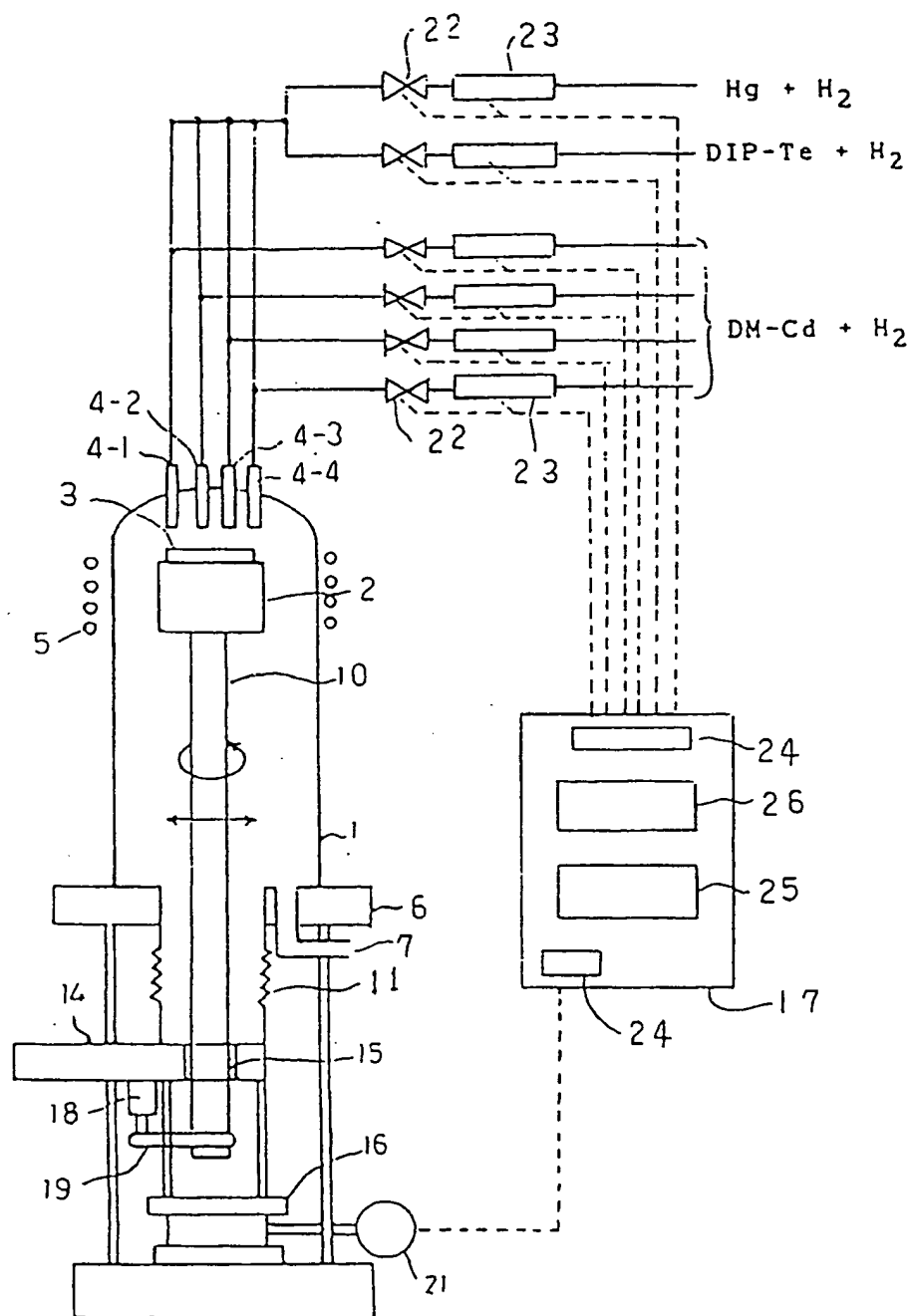


FIG. 7

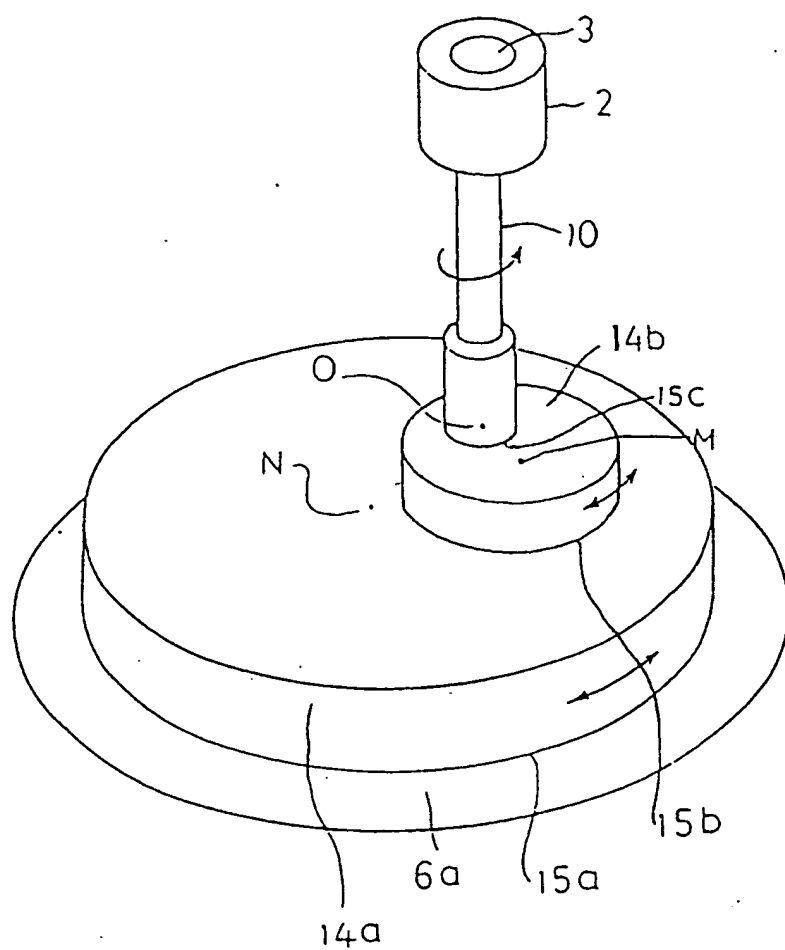


FIG. 8



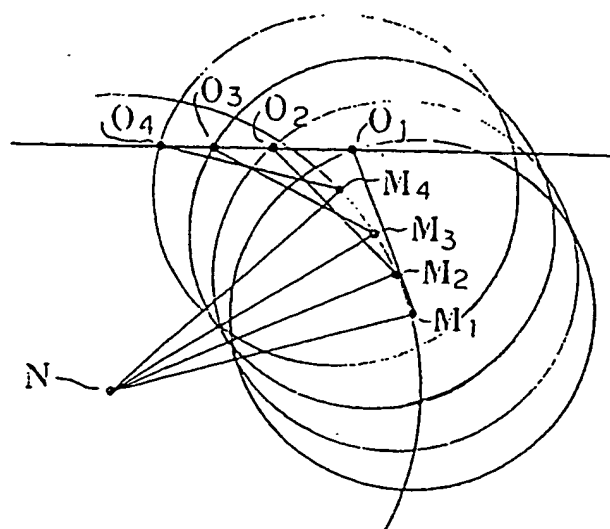


FIG. 9